Characterization of APS Storage Ring Impedance

Advanced Photon Source
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Summary

Impedance of APS storage ring will be characterized by

- Construction of impedance database

- Validation through measurement and tracking simulation

Outline of talk

I. Introduction to wakepotential and impedance

II. Old method and its limitation: motivation for developing new method

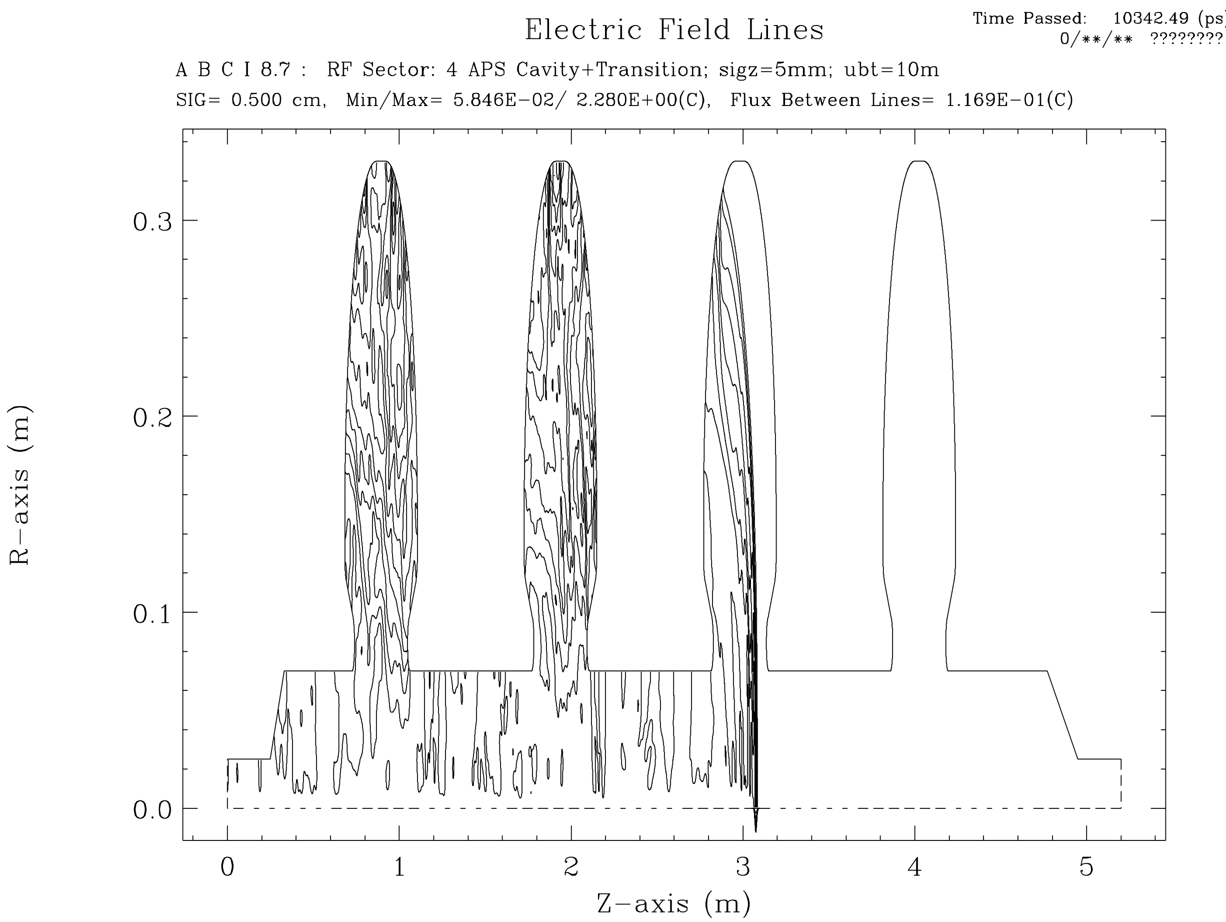
III. Impedance database

IV. Schedule for completion

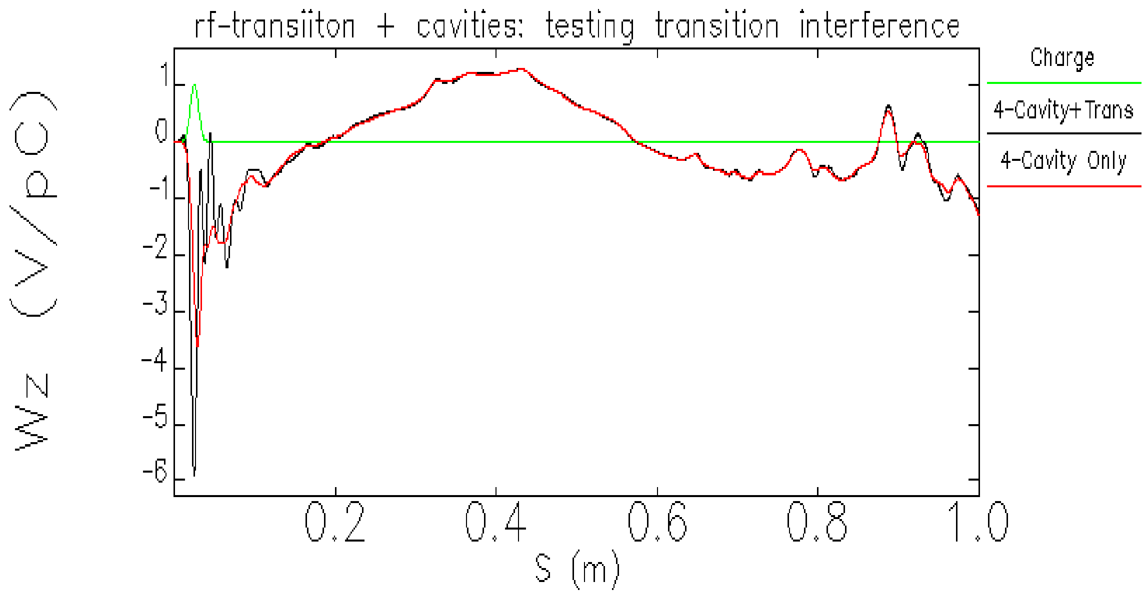
V. Conclusion

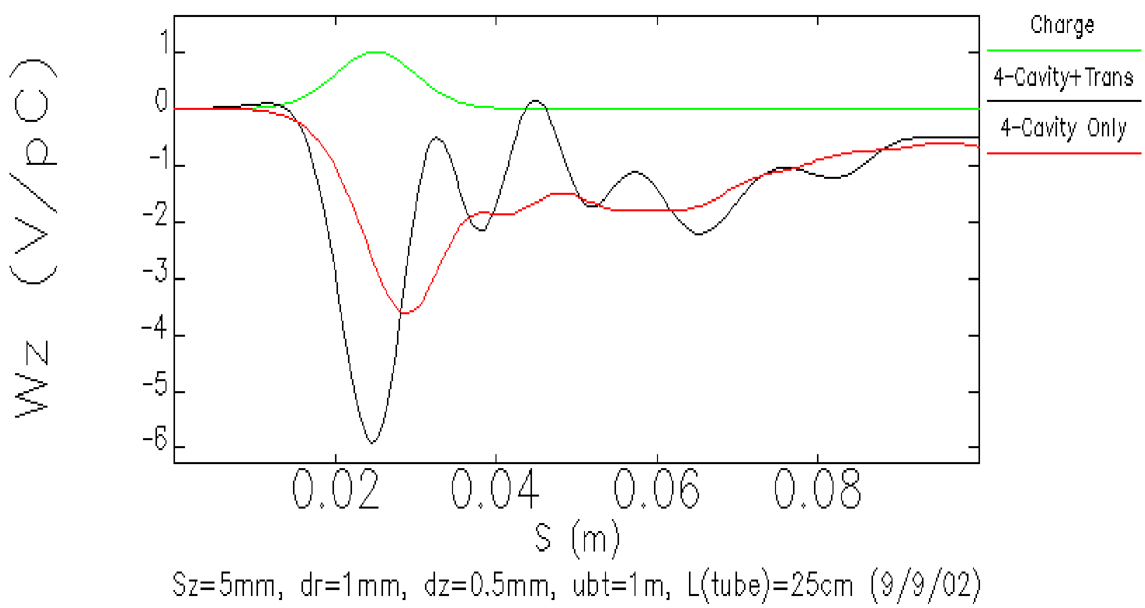
I. Introduction to wakepotential and impedance

Wakefield



Wakepotential





Wakepotential-to-Impedance

- Wakepotential of bunched beam

$$V(t) = \int W(t - t')I(t')dt'$$

- Define impedance

$$W(t) \Leftrightarrow Z(\omega)$$

- Then,

$$Z(\omega) = \frac{V(\omega)}{I(\omega)}$$

- Impedance relates harmonic components of voltage and current. Thus its unit is Ohm, same as circuit definition➔ Broadband Resonator (BBR) Model

II. Old Method and Its Limitation

Broadband Resonator Model

- Definition (R-L-C circuit model)

$$Z_{\parallel}(\omega) = \frac{R}{1 + jQ(\omega/\omega_r - \omega_r/\omega)}$$

- What we really need is

$$\frac{Z_{\parallel}}{n} = \left(\frac{Z_{\parallel}}{n}\right)_0 \frac{(\omega/\omega_r) + jQ[1-(\omega/\omega_r)^2]}{(\omega/\omega_r) + Q[1-(\omega/\omega_r)^2]^2},$$

where $n = \dfrac{\omega}{\omega_0}$

- Only 3-parameters to determine ➔ $Q,\ \omega_r,\ (Z/n)_0$

- It is customary to assume

$$Q = 1, \quad \omega_r = c/b \ .$$

- Then only unknown parameter is

$$\boxed{(Z/n)_0}$$

➔ A number to characterize the whole impedance

➔ Impedance Budget Table

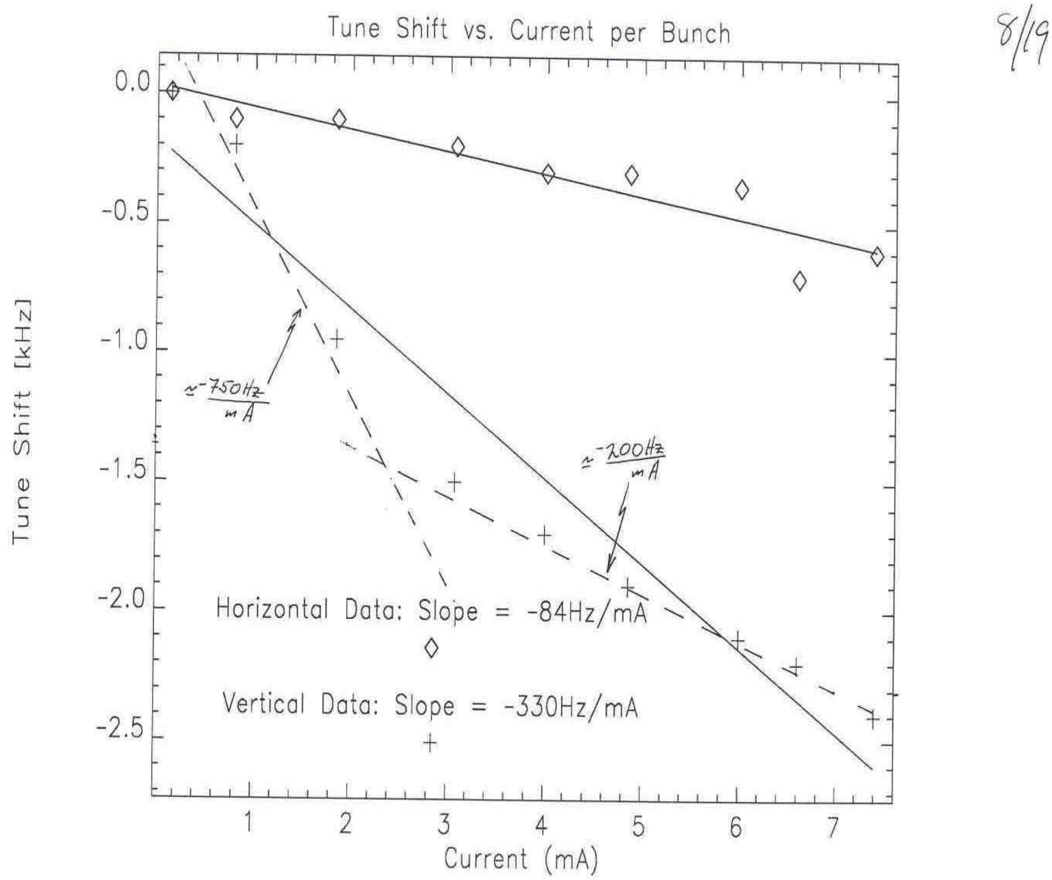
Impedance Budget

APS Storage Ring Impedance Budget

Index	Component	Number	$Z_{\parallel}/n$ (Ω)	$Z_{\perp}$ ($M\Omega/m$)
1	RF Cavity (HOM)	16	0.2	0.02
2	ID Transition	34	0.03	0.06
3	RF Transition	4	0.01	0.003
4	Shielded Bellow	160	0.04	0.007
5	Shielded Transition	80	0.02	0.003
6	BPM	360	0.05	0.01
7	Valve	80	0.01	0.01
8	Crotch Absorber	160	0.01	0.002
9	Flange full-penetration weldment	480	0.01	0.008
10	Ante-Chamber Transition	120	0.003	0.001
11	Elliptical tube weldment	80	0.001	0.001
12	Shielded end conflat	80	0.001	0.001
13	Resistive Wall at cut-off freq.		0.01	0.01
14	Space Charge		1.E-5	0.03
15	Others (kickers,bumpers,ion pump ports, etc.)		0.3	
	Subtotal		1	0.15
	Budget (Subtotal $\times$ 2)		2 Ω	0.3 $M\Omega/m$

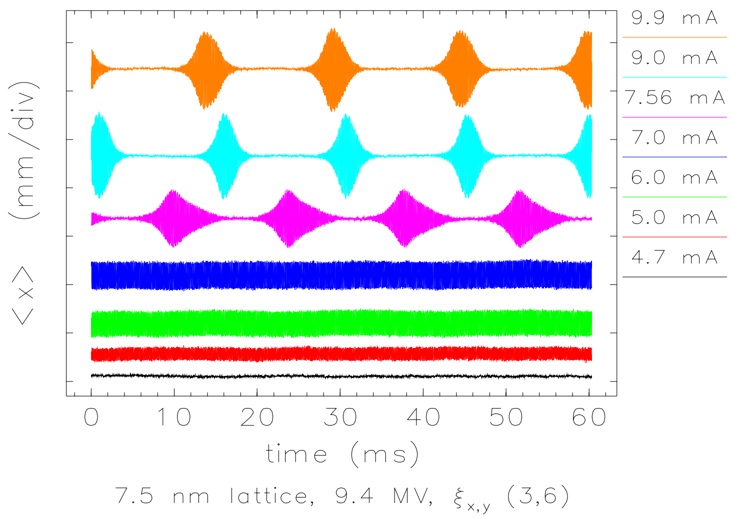
(Compiled by W. Chou, H. Bizek, L. Emery, Y.C. Chae)

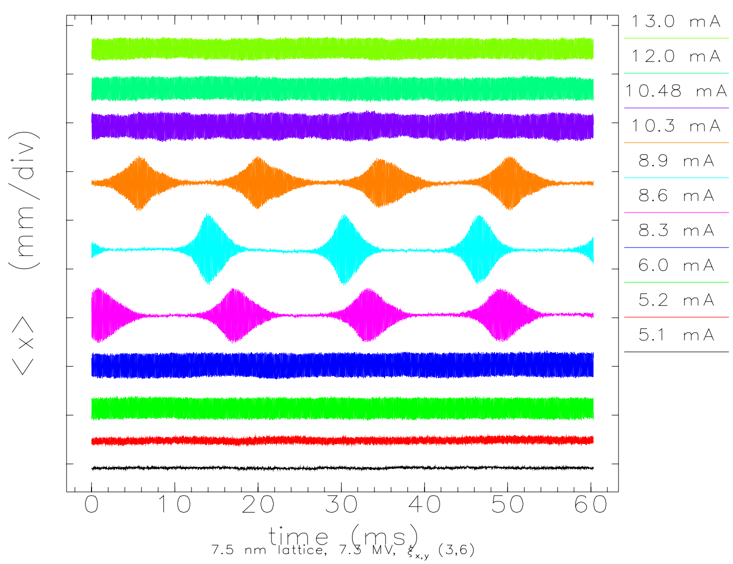
Impedance Estimate by Tune Slope Measurement



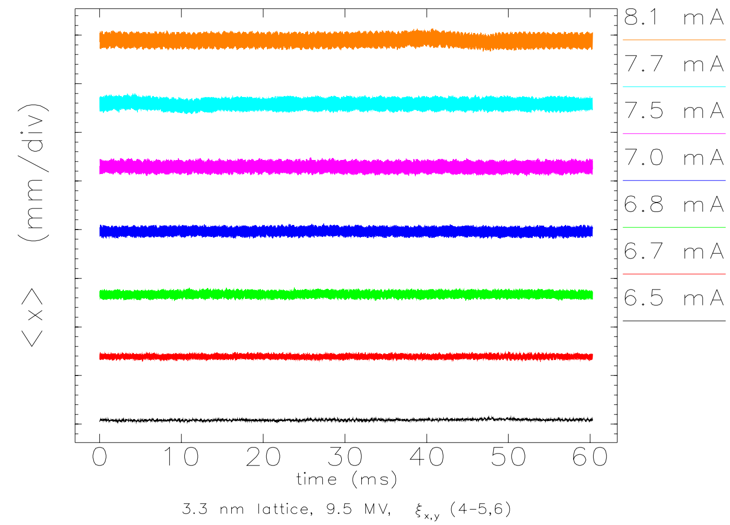
*Tune Slope Measurements: Zt = 0.4 Mohm (S. Milton, 1996)

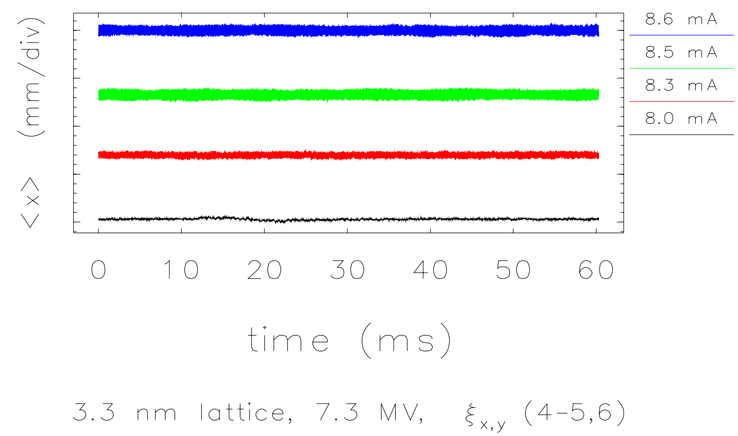
7.5nm





3.9nm





(K. Harkay's)

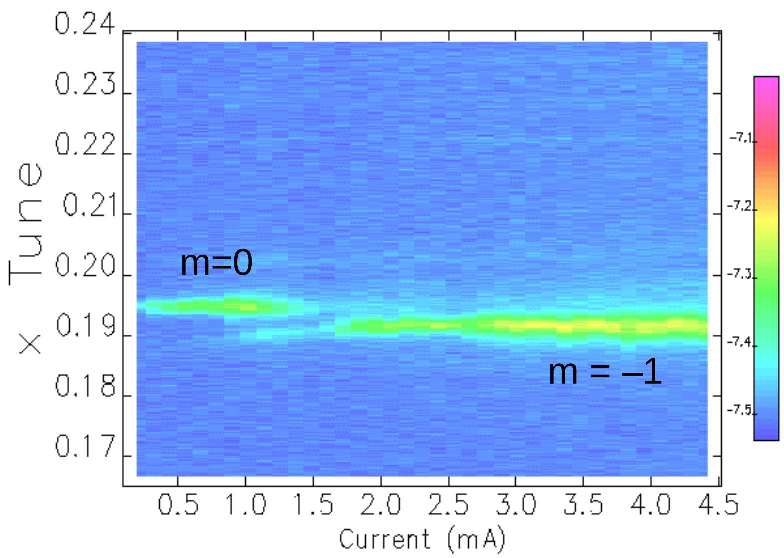
Single bunch instability: transverse mode coupling instability

Force due to transverse wake defocuses beam, i.e., detunes betatron frequency.

When ν_β crosses ($m\nu_s$) modulation sidebands, synchrotron motion can couple to transverse plane and beam can be lost unless chromaticity is sufficiently large/positive.

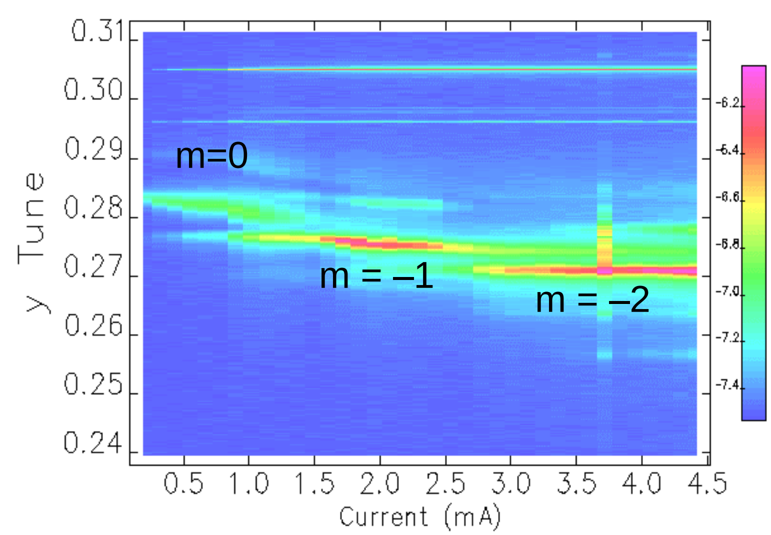
Tune slope increases with no. of small gap chambers: mode merging threshold decreases.

Horizontal



$\Delta\nu_x/\Delta I$ = -8x10^{-4}/mA

Vertical (L. Emery)



$\Delta\nu_y/\Delta I$ = -2.6x10^{-3}/mA

(K. Harkay's)

III. Impedance Database

- Goal

Wakepotential(APS Storage Ring) =

20*(8mm ID Chamber) + 2*(5mm ID Chamber) +

400*(BPM) + 80*(C2 Crotch Absorber) +
……..

- Standardize Wakepotential

1. Data in SDDS format
   - S, Wx, Wy, Wz

2. Uniform simulation conditions
   rms bunch length ➔ SIGz = 5 mm,
   mesh size ➔ dz = 0.5 mm,
   wakelength ➔ SBT = 0.3 m

3. Deposit the authorized wakepotentials in
   ~chae/ImpedanceDatabase/SR
   ➔ Available to everyone to read files

Vacuum Chamber Components

- Old components (experience)

  - Insertion Device Chambers

  - RF Cavities + Transition

  - Crotch Absorbers

  - Horizontal/Vertical Scrapers

  - Septum Intrusion

  - Stripline Monitors ……

- New components

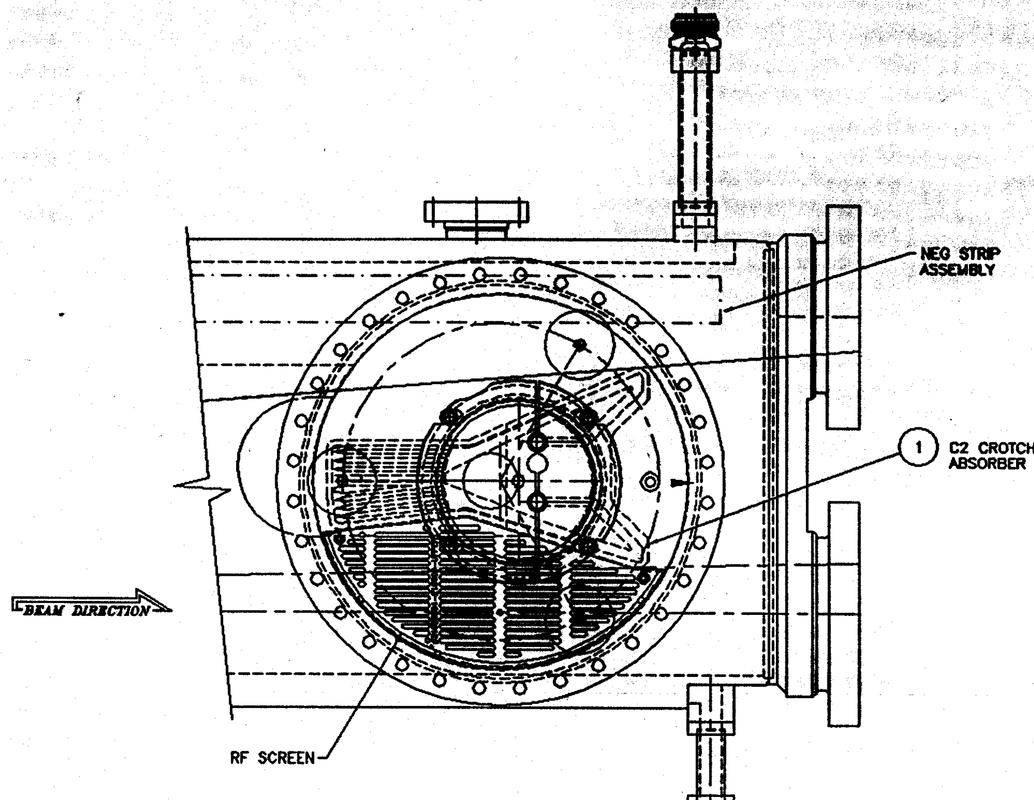
  - BPMs

  - SR absorber between rf cavities

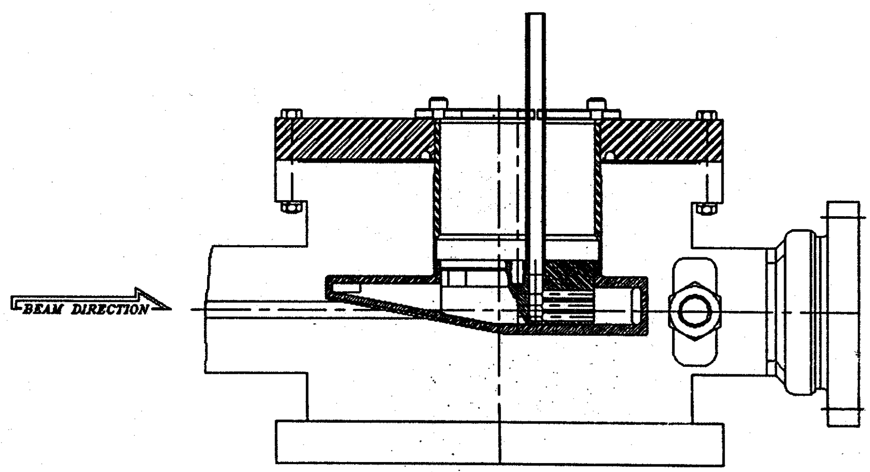
  - Vacuum port (slotted rf screen)

  - Shielded bellow

SR. C2 ABSORBER

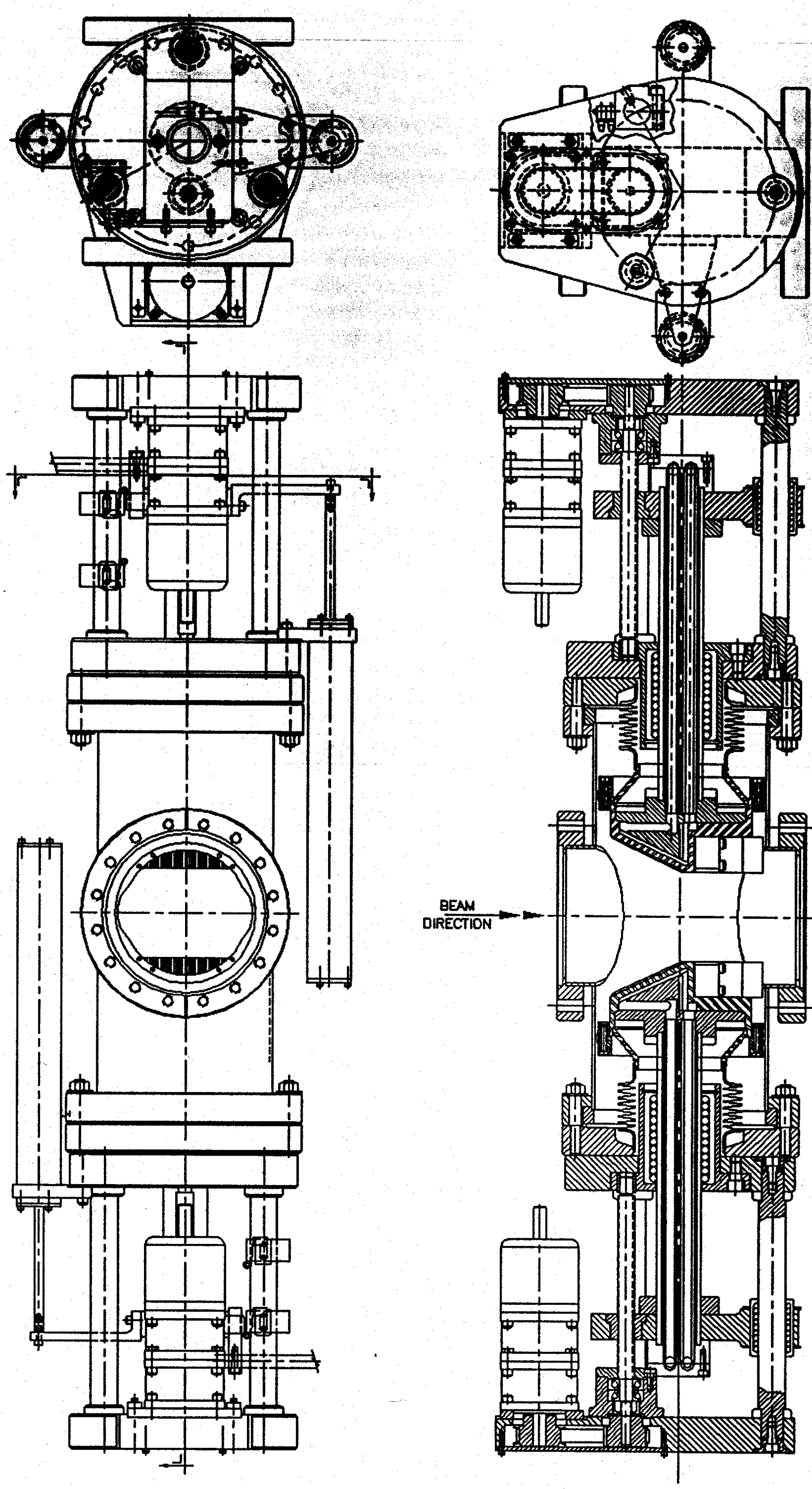


PLAN VIEW
VIEW SHOWN AT TOP OF MOUNTING FLANGE



SECTION VIEW
VIEW SHOWING C2 CROTCH ABSORBER

SR. VERTICAL SCRAPER



Example: Insertion Device Chambers

- **Insertion Device Chambers**

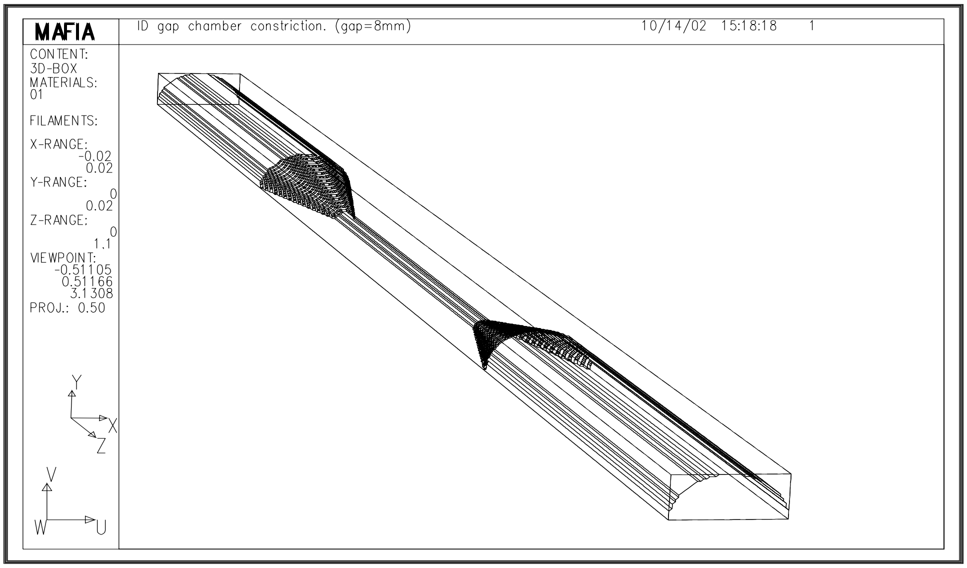
    - 5-mm-gap chamber
    - 8-mm-gap chamber
    - 12-mm-gap chamber

- **Steps taken for 3-D Wakepotential**

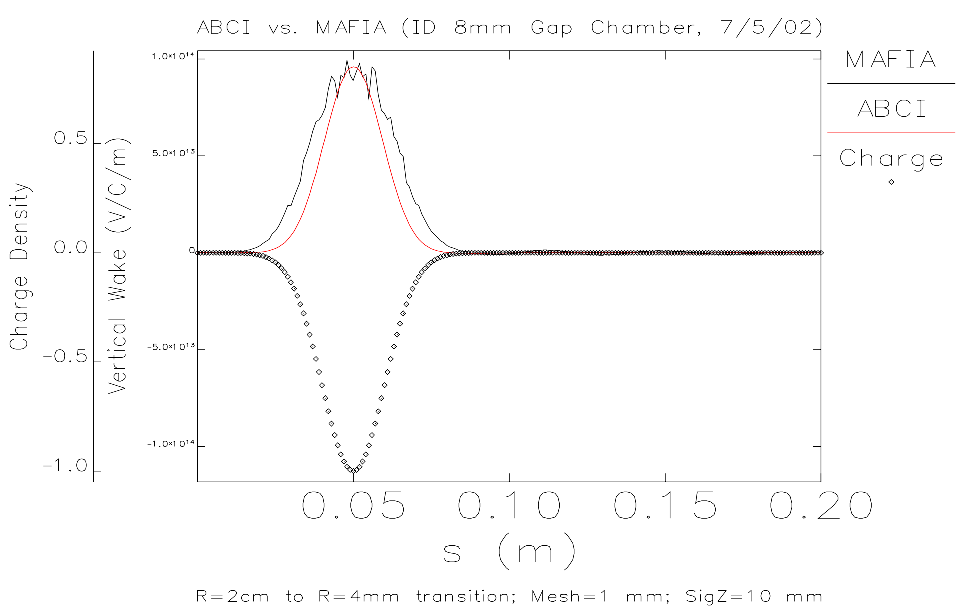
I. 2-D ABCI calculation for circular chamber (High confidence)
II. 2-D ABCI vs. 3-D MAFIA for circular pipe (Compare)
III. 3-D MAFIA for elliptical chamber (Final result)

2-D ABCI vs. 3-D MAFIA (Compare)

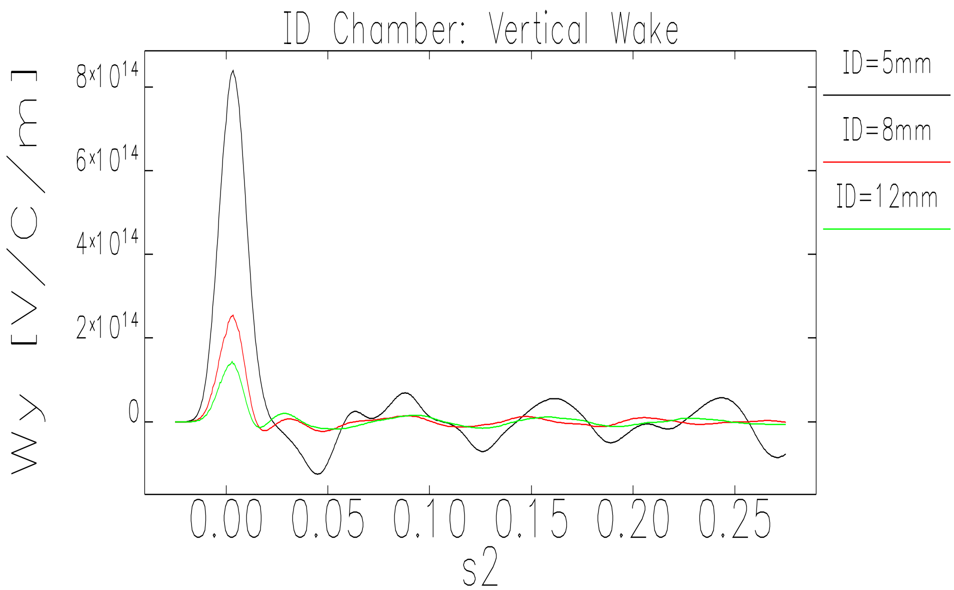
Geometry

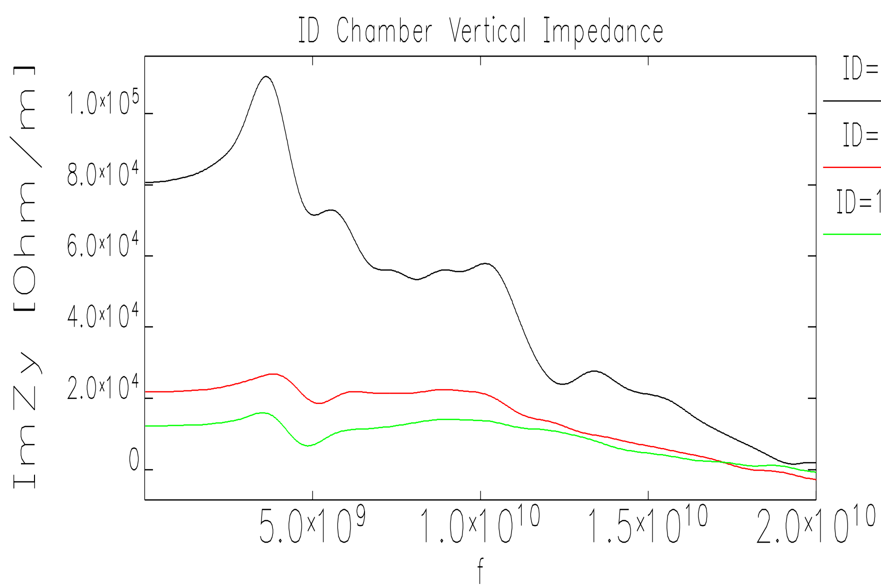


Results



3-D MAFIA Results for Elliptical ID Chamber (Wakepotential & Impedance)





IV. Schedule for Completion

- **Goal**
  Complete "**Impedance Database + Validation"**
  in 8 months (by April 2003).

- **Collaborations for Impedance Database**

  - Drawings provided by Mechanical and Design/Drafting Group

  - Pro/E-based modeling will be interfaced with the commercialized version of MAFIA (Computer Support and Design/Drafting Group)

  - SDDS software support by OAG (Wakepotential combiner, Impedance fitting)

  - Wakepotential calculation by Accelerator Physics Group (Chae), Diagnostic Group (X. Sun)

- **Collaborations for Validation**

  - *elegant* on super-fast “clustered computer” (supported by OAG)

  - Three different impedance/wakepotential options available: impedance in numerical form, BBR model impedance, quasi-wakepotential

  - Chae and Harkay from APG and Sereno from OAG will collaborate in the validation of impedance model via *elegant* simulation

We are looking for the collaboration between labs to measure the impedances by the wire method.

V. Conclusion

- Impedance database provides a uniform framework to characterize the impedance of the storage ring.

- Maintenance of SR impedance as new components are added in the ring becomes straightforward via “standardized wakepotential.”

- Once the impedance model becomes validated, we could predict “dynamic effect” before a new component is installed in the ring.